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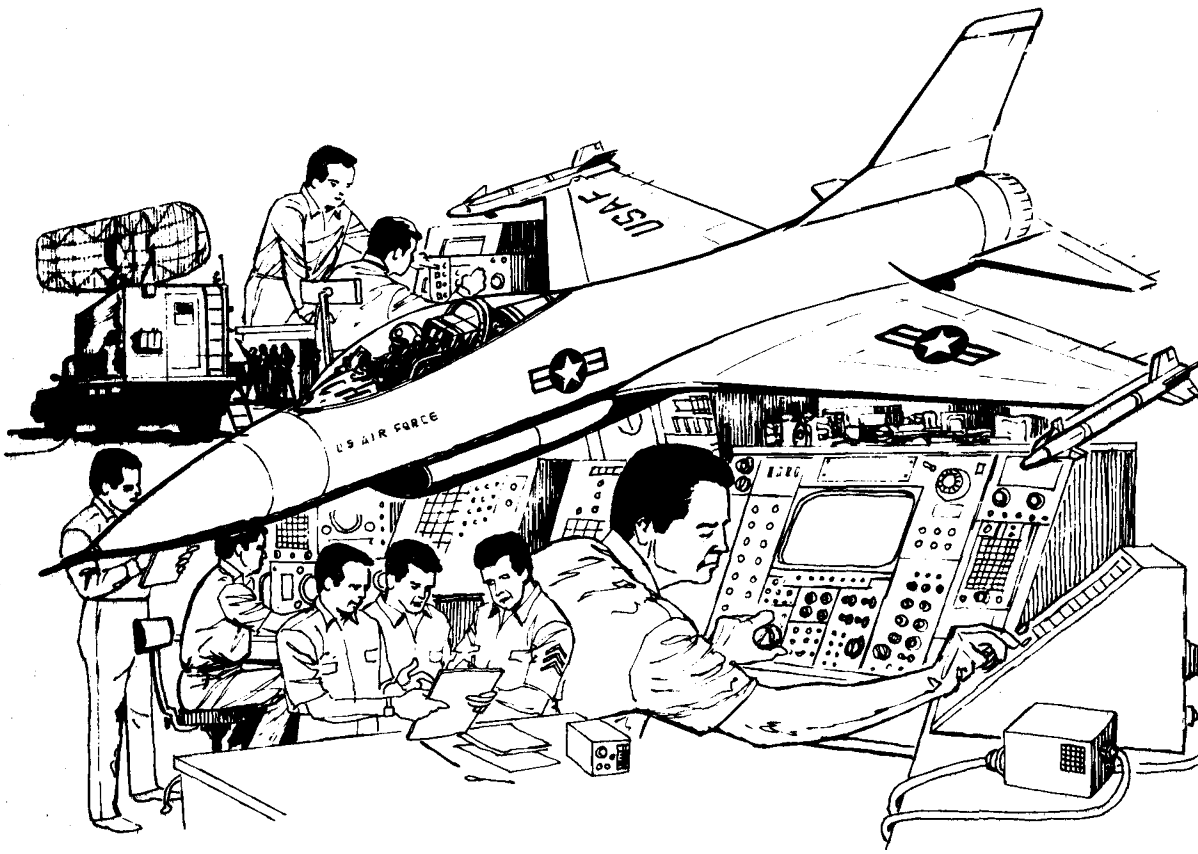

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14. ABSTRACT
The conference on Air Force Training for the 80s presented information on the impact of the all-volunteer force on changing concepts in Air Force training, on developments in Air Force simulation, and Air Force and industry views on contracting of training. This article is from the perspective of the Chief of the Operations Training Division of the Air Force Human Resources Laboratory at Williams AFB AZ.

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TRENDS IN AIR FORCE SIMULATION

An Address to the

Conference on Air Force Training for the 80s

by

Colonel Richard C. Needham

Dr. Bernell J. Edwards

The Air Force mission is to fly and fight. The organization which I represent has a basic role in that mission. Our job is to contribute the best science and technology available to make Air Force operations training as effective as possible. We are the Operations Training Division of the Air Force Human Resources Laboratory. Our function as the leading edge for the advancement of operational training is unique; we are the only organization with such a charter.

The AFHRL set up the Operations Training Division in 1969 at Williams Air Force Base, an undergraduate pilot training center of the Air Training Command. This geographical location facilitates R&D by permitting convenient access to Tactical Air Command activities at Davis-Monthan, Luke, Nellis, Edwards, and Hill Air Force Bases and the Gila Bend Gunnery Range. We're also reasonably close to several Strategic Air Command bases; and as a tenant at Williams AFB, we have direct access to student and instructor pilot populations for research.

Essentially, there are two arms within the Division, working to develop and test technology for operational training. Our engineering R & D provides the hardware systems for training, and our behavioral science R & D develops and tests optimum methods for interfacing the human component with the hardware systems. As this blend of engineering and behavioral technology evolves, it is transferred to the field for implementation by the users, the operational training units of the Air Force.

Our personnel represent a variety of backgrounds in engineering and behavioral science. They come from diverse areas of business, industry, academia, and the military, bringing breadth and depth of experience. A high percentage hold advanced degrees in their fields.

Today, I'd like to review some of our accomplishments and current efforts, and then survey the future of operations training research as it appears from our vantage point. Keep in mind that time will permit only glimpses in these areas. However, we've tried to include key points which give a reasonably accurate profile of our work.

In our simulation research during the early and mid 1970s, we used part-task trainers to demonstrate the potential of simulators for Undergraduate Pilot Training. In a series of studies, we were able to demonstrate potential training time savings in both instrument and contact phases of UPT without reducing pilot quality. The Instrument Flight Simulator now used for Undergraduate Training is based upon these laboratory studies. In the experimental test of the device, potential savings in training time became a reality. To give an idea of payoff, based upon the training of 1,750 UPT pilots, annual savings are at least 90 thousand flying hours and 25 million gallons of fuel. These types of savings allow Air Force managers to reallocate flying time to improve flying training in other areas more important to overall readiness.

The Advanced Simulator for Pilot Training (ASPT), came on line in 1975 and has been used to test and demonstrate several basic, but very important concepts. We have shown, for example, that a simulator of this level of sophistication can train very effectively specific types of flying tasks. The original reason for ASPT was to provide a state-of-the-art simulator capability that could be used to develop and test technology às a procurement guide. The approach has been to use ASPT as a test bed to determine what specific capabilities a device should have to effectively train various tasks.

ASPT has two six-degree-of-freedom motion platforms. Originally, both contained T-37 cockpits. Currently, we have A-10 and F-16 configurations. Aircraft flight dynamics and control loading characteristics are computer-programmable for both the motion and visual systems. The visual display is computer generated through a seven-channel CRT system, providing a 300 degree horizontal and 140 degree vertical field-of-view. The instructor interacts with the student pilot via an operator console of advanced design. This station permits the instructor to manipulate a variety of training conditions and tasks elements.

One of the first concerns in testing ASPT was the relative contribution of platform motion to training effectiveness.

Simulator platform motion is an expensive thing, and costs must be justified in terms of benefits gained. Over the past several years, we have completed a number of studies of the platform motion issue. We've run experiments involving a variety of tasks to determine where differences in learning may occur. Thus far in our studies, platform motion has not been shown to improve training.

These results suggest that simulation dollars are better spent on visual systems and research on other features. Based upon work done in ASPT, a number of research areas can be answered with confidence. That is, we have enough data to predict simulator requirements for given transfer-of-training ratios, and additional studies in these areas would be redundant. These tasks include: normal procedures, emergency procedures, instrument flight, initial air-to-ground, aerial refueling tasks, take-off, landing approach, and close formation.

Important areas where more research is needed to define simulation requirements includes air-to-air tasks, air-to-surface weapons delivery, low level navigation and advanced weapons delivery, tactical formation, force cue requirements for both pilot-induced g-force cuing, and externally induced disturbance.

ASPT's computer image visual system was compared to other simulator visual systems in a study of weapons delivery tasks. This study established computerized modeling as the best approach for this type of task. Answers to these other research questions will require empirical studies to determine how much technology is enough to produce adequate training.

Recent efforts illustrate the kind of inter-service research we produce. We have assisted the Navy in conducting a study to determine field-of-view requirements for carrier landings. We have helped the Army test visual system characteristics leading to engineering design for a new attack helicopter simulator, using the ASPT visual system.

AFHRL has just agreed to a cooperative engineering study with the Army Program Manager for Training Devices (PM TRADE) to develop and test new visual system display technology: a dual TV projector light valve system intended to increase display resolution to human eye limits. Existing weapons systems operate at the limits of the human line-of-sight and beyond. Current simulation displays are unable to provide this level of resolution. The Operations Training Division is the performing organization providing facilities, personnel, and funding to conduct the engineering evaluation and training utility studies. Army PM TRADE is providing matching funding and personnel for the research.

ASPT has proved effective for certain transfer-of-training tasks. We demonstrated that relatively low fidelity simulation training can transfer effectively to air-to-ground weapons delivery skills when flown in the actual aircraft.

The F-5B study was the first effort directly supporting tactical flying training and marked a transition point for our organization toward combined training-research efforts with TAC.

In the F-5B study, we took recent UPT graduates as subjects. Half of the subjects, the experimental group, received an air-to-ground mission in the ASPT; and half of the subjects, the control group, did not receive simulator training. The ASPT was configured as a T-37 aircraft with a gun sight. Both groups flew an actual air-to-ground mission in the F-5B with an IP in the back seat for safety purposes. As Figure 1 shows, the simulator-trained experimental group performed better on all tasks. Air-to-ground tasks offer excellent hard data--bomb and strafe scores--which are more reliable and sensitive than subjective IP ratings.

F-5B WEAPONS DELIVERY RANGE SCORES

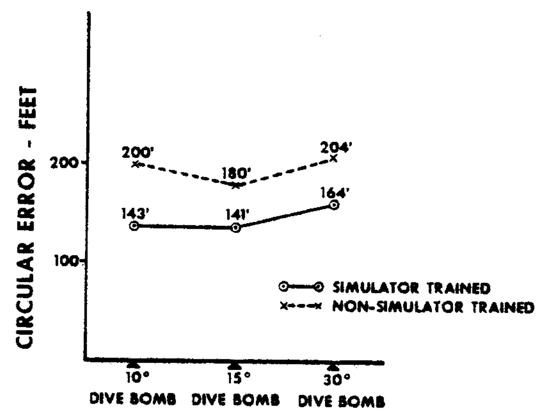

Figure 1.

Our current work with Tactical Air Command in developing A-10 simulation is really an extension of the earlier F-5B study.

One side of ASPT has been changed from a T-37 to an A-10 simulator with transition training capability. In the A-10 training, we have run several experiments in initial air-to-ground training. These experiments have produced some of our most exciting results. We again used an experimental/control group transfer-

of-training paradigm. The experimental group received three air-to-ground training missions in the A-10-configured ASPT. In the strafe task, the experimental group out-scored the control group on all five missions (see Figure 2). In the dive bomb task, their average circular error was better on all seven missions (see Figure 3). This is the first study to demonstrate the durability of simulator training. Past study had indicated the effects of simulator training disappeared after two or three missions; but these effects were still present after seven flights. Some of the simulator-trained, recent UPT graduate who had never been on an air-to-ground gunnery range actually beat their IPs on their first mission. The A-10/ASPT project has been a milestone in simulator research, as well as a good example of AFSC/TAC cooperation. It also shows the value of having a generic simulator that can be modified to meet immediate R & D and training needs. The studies indicate the simulation of air-to-ground tasks has a high transfer-of-training ratio.

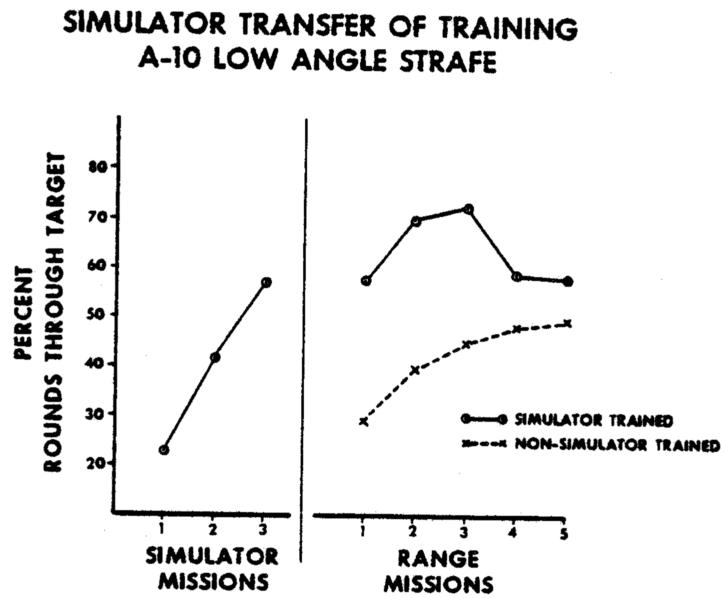

Figure 2.

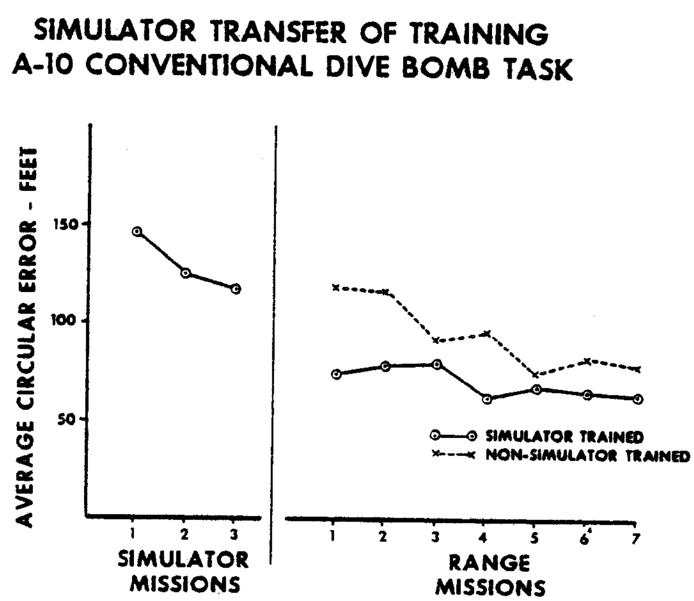

Figure 3.

Results from previous A-10 research of limited air-to-ground weapons deliveries suggested the extension of training into a simulated combat environment for weapons delivery. ASPT's existing visual models were modified to depict a 10-square-mile hostile environment. It had mountains and hills of various elevations and strategically placed anti-aircraft and surface-to-air missiles located in a central valley. An air defense system was modeled so that if the A-10 penetrated the firing envelope of a SAM, the missile was activated. Warning tones associated with SAM acquisition and launch were provided to the pilot.

The target was a tank which could be located at six randomly-selected positions on a road. It had no offensive capability and was considered destroyed by one round from the A-10 cannon.

Combat-ready A-10 pilots participated in the evaluation by flying a mission in which they entered the combat area, attempted to destroy the tank while evading hostile fire, then egressed the area. Pilots flew twenty runs. Each run was terminated as a result of one of the following events: (1) SAM kill; (2) Anti-Aircraft Artillery (AAA) kill; (3) terrain crash; (4) over-G; or (5) safely egressing across the Forward Edge of the Battle Area (FEBA).

The pilots were given an intelligence briefing and a map of the actual location and capability of the air defense threat. The anti-aircraft guns had probability of kill of 100% if the pilot allowed it to achieve a tracking solution for six seconds. If fired, the SAM could be evaded by proper maneuvering. This was much harsher than the pk of air defense systems but was used to reduce experimental variability. A muzzle flash was used to aid the pilot in finding the tank, and the tank was not camouflaged.

Performance results were analyzed on the basis of whether the pilot hit or missed the target, survived, or was destroyed. All seven participants show increased performance in offensive and defensive skills (see Figure 4). After ground impact and overstress losses were removed from the first two runs, the learning curves were similar to those of actual combat and indicate this kind of training should improve a pilots survivability, particularly during the first combat missions.

Judging from these results, there is no reason why combat scenarios cannot be modeled and trained in a simulator. If losses can be decreased in the first few missions of a war by simulation, then this type of training can become a force multiplier.

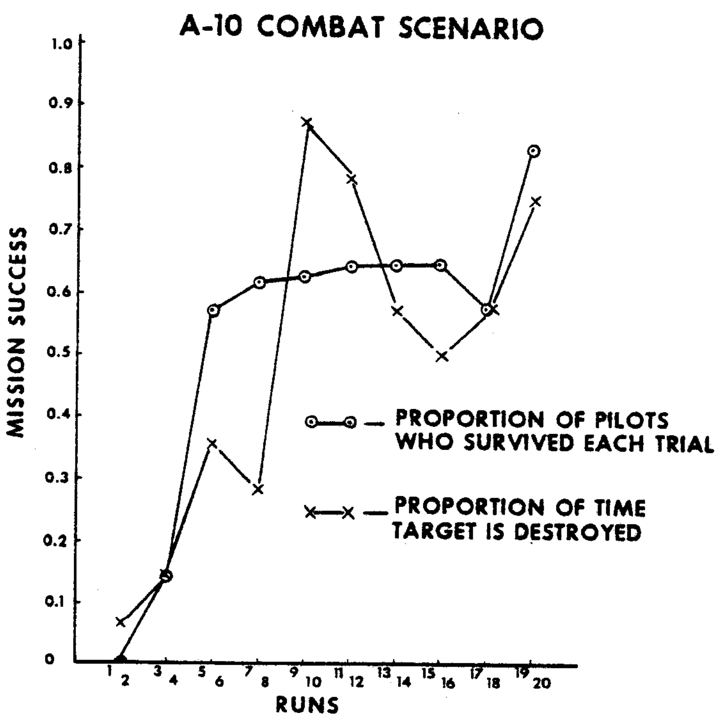

Figure 4.

Another part of A-10 R&D involves using ASPT to train pilots in the use of the A-10 Manual Reversion Flight Control System (MRFCS) and degraded flight control mode. At present, this training is not done in the actual aircraft because of the safety risk. We are using ASPT to investigate the cues required for successful training to maintain aircraft control when in the manual reversion mode.

Data results are in and are clear-cut. The MRFCS mode is trainable through simulation, and it is likely that a simulator-trained pilot can fly a battle-damaged aircraft to a point where he could safely land or eject. Some specifics in the data show that a wide field-of-view in the simulator produces better pilot performance for this task; that the more complex the failure mode, the poorer the pilot performs; and that the presence or absence of platform motion does not affect performance in any failure condition. The MRFCS problem provides an excellent demonstration of the training advantages afforded by simulators in teaching those things that cannot be taught safely in the aircraft.

The F-16 simulator development program is our second major effort for TAC. It essentially follows the precedent set by the A-10 effort. We've built a basic F-16 simulation into ASPT so that TAC can have simulator training for F-16 pilots while awaiting delivery of their operational F-16 simulator. For research, we have an initial vehicle through which we can address several high priority R&D issues. These include the training impact of simulated turbulence and the effectiveness of wide field-of-view simulation on training for F-16 initial transition and air-to-ground weapons tasks. In a second phase of engineering development, the ASPT F-16 simulation will undergo intensive improvement. This will provide a refined F-16 simulator with a potential for broader scope, more demanding R&D -- particularly in the air-to-air skills phase.

Another important current effort within our organization is Project SMART, Skills Maintenance and Reacquisition Training. This effort is central to the Air Force concern for maintaining adequate aircrew readiness while conserving energy resources. The essential thrust of SMART is toward objective flying skills measurement.

To date, development of skill measures has focused on B-52 aircrew proficiencies. Some of our greatest success has been in this area. B-52 research has been along several lines -- crew coordination, task analysis, and, more recently, radar bombing skills. Measures of pilot performances are underway.

Training design people identify crew coordination as a continuing problem at all training phases. Research growing out of work in this area has identified performance factors of greatest importance in crew coordination. These findings provide a starting point for better crew interaction through training programs.

Intensive work at Castle and Mather AFBs has produced a mathematical model for bomb and missile delivery accuracy. Radar Bomb Site (RBS) scores were analyzed by types and magnitudes of inaccuracies in various types of weapon releases. The statistical procedures applied in this work have proven a powerful means of accomplishing two critical steps: (1) describing B-52 weapon delivery accuracy, and (2) identifying the exact sources of inaccuracy for specific delivery techniques. Thus, through this analysis, corrective requirements can be identified and improved training provided.

Project SMART anticipates future training requirements under critical energy constraints. It will identify what skills must be practiced and to what degree to maintain mission-ready aircrews.

Conventional use of simulators has been mainly for transition and instrument training. Units with simulators have used them as substitute aircraft for parts of their training programs. With the advent of sophisticated full field-of-view simulators such as ASPT, it has become apparent that these devices have potential for interactive training scenarios between geographically separated units.

We recently demonstrated this capability by linking ASPT with TAC's Simulator for Air-to-Air Combat (SAAC) located at Luke AFB. This was a pioneering accomplishment showing the potential for extending the simulation concept to combined arms training. Future applications might include air-to-air refueling between the receiver and tanker unit, friendly versus enemy encounters between air superiority aircraft of two tactical units, and bomber versus fighter situations, to name a few.

Having reviewed some of our past and present R&D efforts, I'd like to turn now to the future -- a look at where we are going in operations training R&D.

Our long-range goal is to develop a high technology base for training air combat skills through simulated combat environments. The target date is FY 87. As we evolve this technology, we expect intermediate transfer of products, that is, hardware and methodology, to user commands. The final test of training effectiveness is crew performance in combat. The better the training, the better the aircrew will perform in combat and the greater their survivability. In the October 1973 Middle East War, Arab military forces, using Russian SA-6 and SA-7 SAMs coupled with ZSU-23-4 AAA,

inflicted heavy losses on Israeli aircraft. The high cost of admission to the first ten days of a war is well-documented in projected aircrew/aircraft attrition figures. Generally, five major causes are cited as contributing factors, and three of these are directly related to skill deficiencies caused by the inability to practice certain critical skills in the air in a peacetime environment. Aircrews aren't practicing maneuvers to evade surface-to-air missiles; bombing and strafing practice doesn't include actual AAA fire or field launched heat-seeking missiles. As many threat aircraft and weapons are not replicated in U.S. inventories, they cannot be faced as adversaries in aircrew training. The experience accrued by the pilot who survives the first ten days of battle tends to increase his survivability, providing a force multiplier.

An effective means of introducing aircrews to the combat situation, which permits them to practice critical skills under the stress of engagement without actually being in a battle, would represent a quantum leap in training technology. The vehicle to do this is simulation and the capability to assemble and employ the essential aspects of the combat encounter for aircrew training only awaits development.

The one vehicle by which aircrew training systems can make up this deficiency in critical combat skills is the Weapon System Trainer (WST). We currently employ training simulators in a substitution role, using the devices to practice skills which could otherwise be practiced in the air if flight time were available. The future role of simulation, however, recognizes the simulator's ability to capture threat environments and teach critical combat skills which otherwise cannot be practiced in peacetime.

The end product of our air combat training thrust over the next seven or eight years will be the high level technology needed to effectively reduce first mission attrition ... in other words, to put a more fully prepared aircrew member into combat. This technology will also permit units to predict levels of combat readiness using empirical data (hard numbers), exacting design criteria for simulators, and strategies to optimize the training method-media mix.

The majority of flying tasks are heavily loaded with visual skill components. Consequently, it is very important to identify and define visual cue requirements for air combat training. This is probably the single most important research area because of its great impact on training cost and effectiveness. We have identified the low-level flight task as the most demanding combat training problem. Yet, visual simulation technology is most limited for this task because the level of visual detail required is much higher than present technology can accommodate. This will require considerable further development. Requirements for training the visual tasks associated with the low-level environment must be identified and developed in order for full-mission simulation to be effective.

As we proceed on this problem, our behavioral researchers working with our engineers will be testing the training utility of various visual system improvements, such as scene detail (resolution), additional dynamic modeling of the environment, and color, to determine where development is sufficient to produce required training effectiveness. This pattern of technology development and testing will be pursued in a number of areas as hardware state-of-art progresses. This will also be extended to include technology relevant to the vital area of combat tactics development.

Tactics training will address the full range of Air Force flying training. The goal of this work is to demonstrate the application of simulation to full mission combat training and determine its utility for tactics training. The goal is not to develop tactics against specific tests, but to give users the information necessary to develop cost-effective simulators and analysis tools to evaluate tactics. We intend to put the aircrew in the performance loop rather than using computers to determine outcomes. The results of our A-10 combat study indicate that a pilot can learn the cognitive skills necessary to survive an air defense environment and destroy his assigned target. Assuming a pilot can learn the cognitive skills necessary to penetrate, neutralize, and egress a variety of air defense systems in a simulator, then a substantial reduction of losses in the first few days of a war could be expected. If NASA can simulate moon landings, flight simulators should be able to reach a "dial-a-threat" capability to train aircrews in their assigned combat mission.

We intend full development of a simulated hostile environment for several reasons: it will produce better combat-ready pilots; it will force technological development in low altitude flight skills benefitting visual nap-of-the-earth simulation; it will provide a test-bed for measurement of combat performance; and it may lead to the eventual merging of a simulated air and ground operations.

As we approach further development, a concept of fidelity is emerging somewhat different from the traditional notion. To simulate combat conditions, what seems important are those variables known to affect the outcome of engagements, and which can be quantified. Thus far, several areas of development are under consideration for the expanded combat simulation model.

At a high priority is visual terrain simulation. A-10 close air support training will require the best characteristics available. The data base should provide suitable likeness of European and Mid-East terrain to match A-10 operational environment -- mountainous, rolling, and desert area of central Europe and the Sinai Canal west of the Mitla Pass. The Defense Mapping Agency has digitized data bases for these areas. The Army has considered these areas for its Armour Full Crew Research Simulator.

Data base comparability could pave the way to inter-service research and combined-areas training over common terrain. The visual system should be interactive with the entire system for on-line development and update. The A-10 visual base should be large enough for aircraft launch from forward staging areas and for navigation to coordinates of deployment.

The visual simulation of maneuver elements on the ground will be important. It should provide both friendly and hostile forces in the FEBA. The system should impose the A-10 close air support scenario over a pre-programmed ground battle. The battle scale should be on the order of two Red tank regiments against one reinforced Blue tank battalion. This scale corresponds to a reasonable level of simulation for close air support engagements.

Moving models would be provided within the pilot's visual scene. When approaching a battalion-size unit from a large slant range, a single moving model could depict unit movement as a whole. As the A-10 approached, movement of individual companies would be portrayed with several models. Then, when the A-10 was within attack range, moving models could be used to show individual vehicles as required. Experimentation is needed to define precise limits for this order of simulation. Visual feedback for training will be important. The system should have a look-back or reverse display so that the pilot can see how his own aircraft is seen from positions on the ground. An instructor/operator could position ground weapons within the computer-generated visual scene as viewed from other ground positions.

The visual system should provide augmented visual cuing, such as surface-to-air missiles appearing as transparent light effects to be avoided. Simulated AAA fire would be another form of augmented cuing. Early in training, all AAA would be simulated as tracers; later in training as the pilot progressed in skill, the frequency of tracers would decrease as a cue fading device. Varying the apparent size of visual objects would be yet another cue-augmenting technique, such as showing a missile larger than lifesize to aid early detection and avoidance.

Varieties of weapons systems and their effects would be provided, such as all key-threat ground and air defense weapons. A Soviet tank regiment includes, for instance, 95 medium tanks, three light amphibious tanks, 20 APCs and BRDMs, four SA-9s, four ZSU-23-4 anti-aircraft vehicles, and a vehicle launch bridge. Full development of the Soviet air defense capability should also be provided.

For battle scenarios, the instructor would be able to select the presence or absence of specific weapons, their position and firing characteristics, engagement strategies, the effect of smoke, ECM, and other elements affecting battle interaction programmed as hit probabilities. For instance, the A-10, when hit by AAA fire, might go into manual reversion mode. The suppressive effects of air-to-ground fire would also be provided to alter the firing probabilities of ground units. The system would provide simulations of all threat emitters and their manual or pre-programmed operation. Cockpit simulation would include all EW and ECM functions.

Active and pre-programmed control of tactical aircraft other than those piloted, such as planes in formation, forward air controller, and attack helicopters would be available, as would all communication modes between these elements. An instructor/operator could position weapons on the ground using a light pen and CRT display. This would provide feedback needed by the operator to set up a fire plan while positioning weapons for a combat scenario. The graphics system would telescope displays so the operator could "zoom in" for detail in specific areas of interest.

The system would have on-line, three-dimensional playback similar to that on Air Combat Maneuvering Instrumentation (ACMI). This would provide a visual trace of the flight path, aircraft state parameters, threat envelopes, and indications of when air defense system tracks an aircraft. Graphics playback would feature slow motion and freeze modes.

In order to bring about the high level state-of-the-art necessary for future visual and other simulation technology, we are looking at a formidable engineering thrust. Our engineers are moving forward in a number of hardware areas, eventually integrated to produce a full-mission air combat training system. This engineering development corresponds with the goals of our behavioral research for FY 87. Our goal overall is to develop the required hardware through product oriented R&D, conduct empirical training evaluations in user-oriented environments, and transfer both hardware and training effectiveness to the field as soon as possible.

There are two thrusts. One, in a series of immediate and longer range updates in the ASPT; and, two, intensive development of visual simulation technology. ASPT updates will include modularization of aircraft types for rapid cockpit changeovers including programmable control loading and flight dynamics and provisions for manual reversion flight control system simulation. The ASPT visual system will also receive continuing updates to include addition of moving ground models, increased edge capacity and circle generation for more realistic scene content, helmet-mounted sensors and displays for improved pilot perception, and replacement of aging CRTs. These improvements will move us nearer to comprehensive engagement-simulation technology to support full-mission combat training. These are, of course, interim steps toward that goals.

The second engineering thrust, the intensive visual system development, we expect will produce great advances in visual simulation. Some of these developments will include: a flexible, modular image generation design to complement a modular rapid-change aircraft/cockpit capability in ASPT; additional increases in edge capacity and circular features-generation; and color and texturing enhancements to permit highly detailed, realistic scene displays. We expect to expand from seven to ten visual channels for a near 360 degree field-of-view.

This level of engineering and behavioral R&D will make possible flying training on a scale scarcely conceived of as yet. It will give us the means of practicing combat missions under conditions which approach actual combat. This will move the Air Force into a wholly new concept of training. The relationship between tactical performance in the simulator and readiness levels needed for combat success will be determinable. This will permit us to know, in advance, if and to what extent, increased training costs will produce necessary training effects. A pilot will become highly proficient before going against a real enemy so that his chances of success can be accurately predicted. Aircrews will benefit from rehearsal of full missions under realistic threat conditions.

In the final analysis, the success of any R&D effort is measured in terms of user acceptance. When the benefits of science and technology are operationally realistic and are fully implemented by the user, we can expect to move nearer to the ultimate goal of combat success for all aircrews.

Colonel Richard C. Needham

Colonel Richard C. Needham is presently Operational Training Division Chief of the Williams AFB, AZ. Prior to this position, he served as Chief, Flying Training Branch, Deputy Chief of Staff for Personnel, Headquarters USAF.

His duties include responsibility for the operation and conduct of research on the world's most advanced flying training research devices.

Col. Needham received his Bachelor of Science Degree from the University of Nebraska. Commissioned a 2nd Lieutenant, his initial Air Force assignment was as a Radar Observer in the 75th Fighter Squadron at Presque Isle AFB, ME. He attended pilot training at Moultrie AFB, GA and Webb AFB, TX. After gunnery school in F-86F aircraft, he was assigned to Greenville AFB as an instructor pilot in T-33 aircraft. During this period with Air Training Command, he also served as a T-37 instructor pilot at Williams AFB, AZ.

A command pilot with over 4500 hours of flying, Colonel Needham's military decorations include the Silver Star, the Distinguished Flying Cross, the Air Medal with seven Oak Leaf Clusters and three Presidential Unit Citations.